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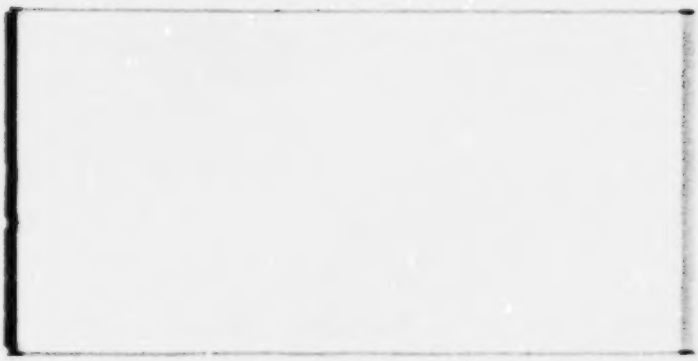

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# LABORATORY STUDIES OF FISH RESPONSE TO POROUS CCW INTAKES - 1981

Report No 84-79-K

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## ABSTRACT

Responses of alewife, rainbow smelt, yellow perch and pumpkinseed sunfish to full scale segments of a natural stone porous veneer intake and four manufactured porous intake surfaces were tested in a laboratory model in daylight and twilight. Fish capture data were insufficient to evaluate the relative merits of the various intake surfaces tested. In 422 one-hour tests (21 100 fish) only 13 fish were captured (11 by an open-pipe control intake). Data on encounter frequency indicated some avoidance of the manufactured surfaces relative to the stone intake, and encounter pathway data suggested that greatest avoidance was obtained with those manufactured surfaces having visible surface contour. However, differences between intake surfaces were not clearly defined. Factors such as the species tested (benthic or pelagic), illumination level (daylight or twilight) and tank currents (especially cross-currents) influenced activity levels, encounter pathways and encounter durations much more than the intake surface used. In future studies of intake surfaces, efforts must be made to assure that the laboratory system is capable of capturing a substantial proportion of test fish.



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To Dr. W.R. Effer
Manager
Environmental Studies and Assessments

# LABORATORY STUDIES OF FISH RESPONSE TO POROUS CCW INTAKES - 1981

J.S. Griffiths

## 1.0 INTRODUCTION

This report describes laboratory studies of fish response to a new cooling water intake, the porous veneer or precast porous bottom (PPB) type, developed by members of the Ontario Hydro Capitalized Once-Through Cooling (COTC) task force. The present study was requested by the Environmental Studies and Assessments Department (Project 820-09909) with funding being provided from the COTC program. This report describes the initial (1981) laboratory studies of fish response to the PPB intake. Further laboratory studies of this intake (1982-83) have been previously reported (Ontario Hydro Research Division Report 83-351-K). Details of the conceptual development of the PPB intake may be found in that report, as well as Design and Development Division Reports 82434, 82490 and 82650.

In the present study, the responses of wild Great Lakes fish species to four manufactured porous intake surfaces and a natural stone veneer were tested in the laboratory, using flow rates expected in a full-scale intake. Test intakes were limited to a diameter of about 2 m due to pumping capacity limitations of the laboratory model. Tests of avoidance response were conducted under low level daylight (approximately 10 lux) and twilight ($10^{-3}$ to $10^{-4}$ lux). Alewife *(Alosa pseudoharengus)* and rainbow smelt *(Osmerus mordax)* were used as representative pelagic schooling species. Yellow perch *(Perca flavescens)* and pumpkinseed sunfish *(Lepomis gibbosus)* were used as representative benthic species. Tests were conducted in the presence and absence of simulated lake cross-currents (two velocities) as well as the intake flow.

## 2.0 APPARATUS AND METHODS

### 2.1 Intake Test Facility

The submerged intake test tank constructed by Hydraulic Studies (previously used for scale-model tests of velocity cap intakes) was modified for the present study. The facility consisted of a large (15 m) square concrete tank equipped with three pumps (0.113 $m^3/s$ each) to create a cross-current flow. A fourth pump of similar capacity was used to withdraw water from the center of the tank. This "intake" flow was returned via a circular ring pipe around the periphery of the tank (Figure 1). The tank was partially filled with gravel to cover the internal pipes and provide a uniform level bottom. Only the cross-current intake and discharge pipes, the ring pipe and the intake inlet were exposed.

Gravel within the ring pipe was leveled to provide a uniform test area with a water depth of about 56 cm. A wire mesh fence was added to retain fish within the ring pipe (approximately 12 m in diameter). Excess gravel was formed into berms at the upstream side of the ring pipe to direct the cross-current flow towards the centre of the tank, as the ring pipe tended to divert the flow towards the tank walls. Current measurements taken after modifications indicated that a reasonably uniform cross-current flow of up to 7 cm/s could be obtained. The capacity of the intake pump determined the size of the intake surface which could be tested. As the design velocity called for a through-port velocity of 15 cm/s (average 5 - 6 cm/s integrated over the entire intake surface) it was possible to produce full-scale velocities with a porous surface approximately 2 m in diameter. As this was the size of the existing concrete basin surrounding the intake pipe, the basin was retained as a support structure for the test intake surfaces.

### 2.2 Intake Surfaces

Five porous intake surfaces were selected for testing, following consultation with other COTC program members, including representatives from Environmental Studies & Assessments, Hydraulic Studies & Development and Civil Design. The test surfaces are shown in Figure 2 and described below.

Although the natural stone veneer was expected to be unsuitable for use (due to probable instability under wave action and irregular flow patterns) it was retained as a reference surface for biological tests, as it presented a relatively natural substrate for the fish. The veneer used in the present tests consisted of a single layer of 20 cm to 30 cm diameter stones

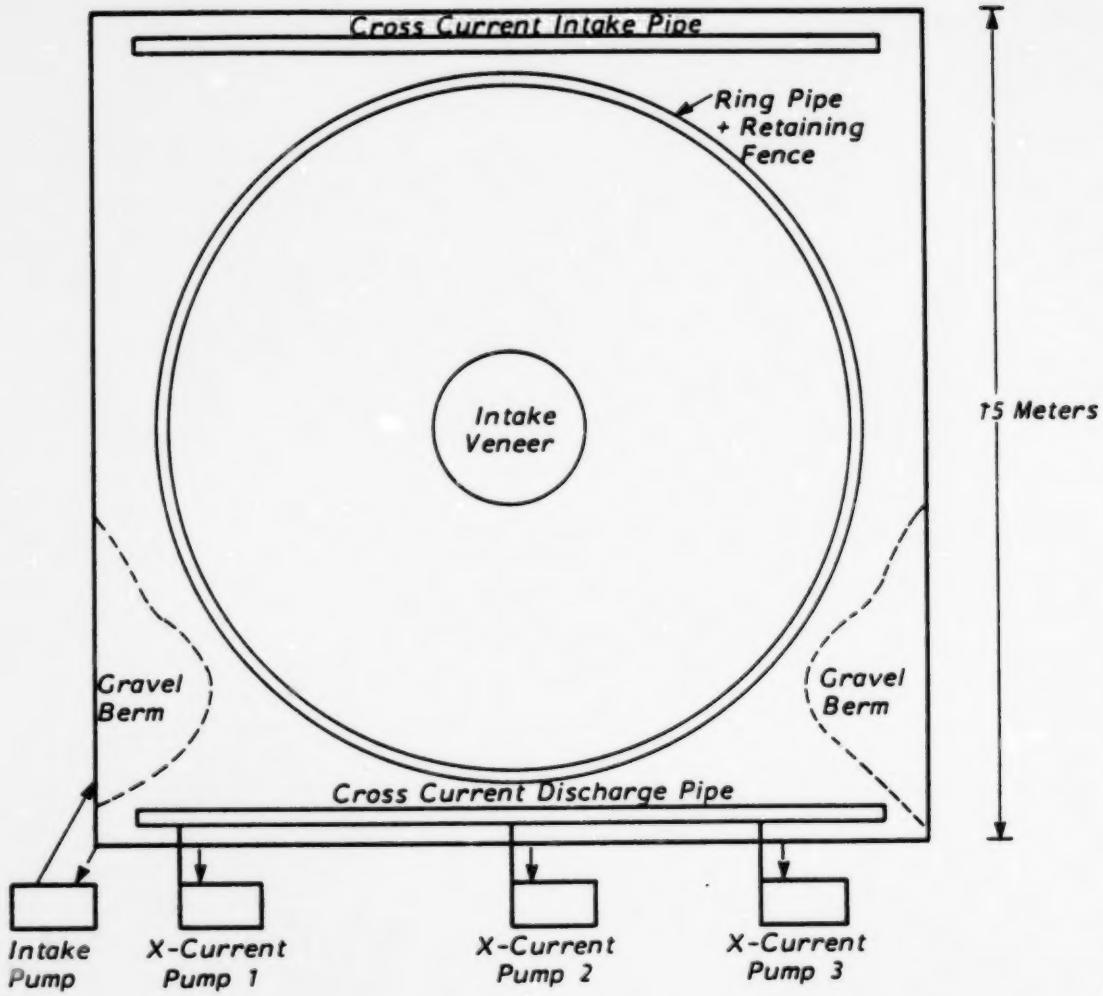



**FIGURE 1**

**POROUS VENEER INTAKE TEST FACILITY**

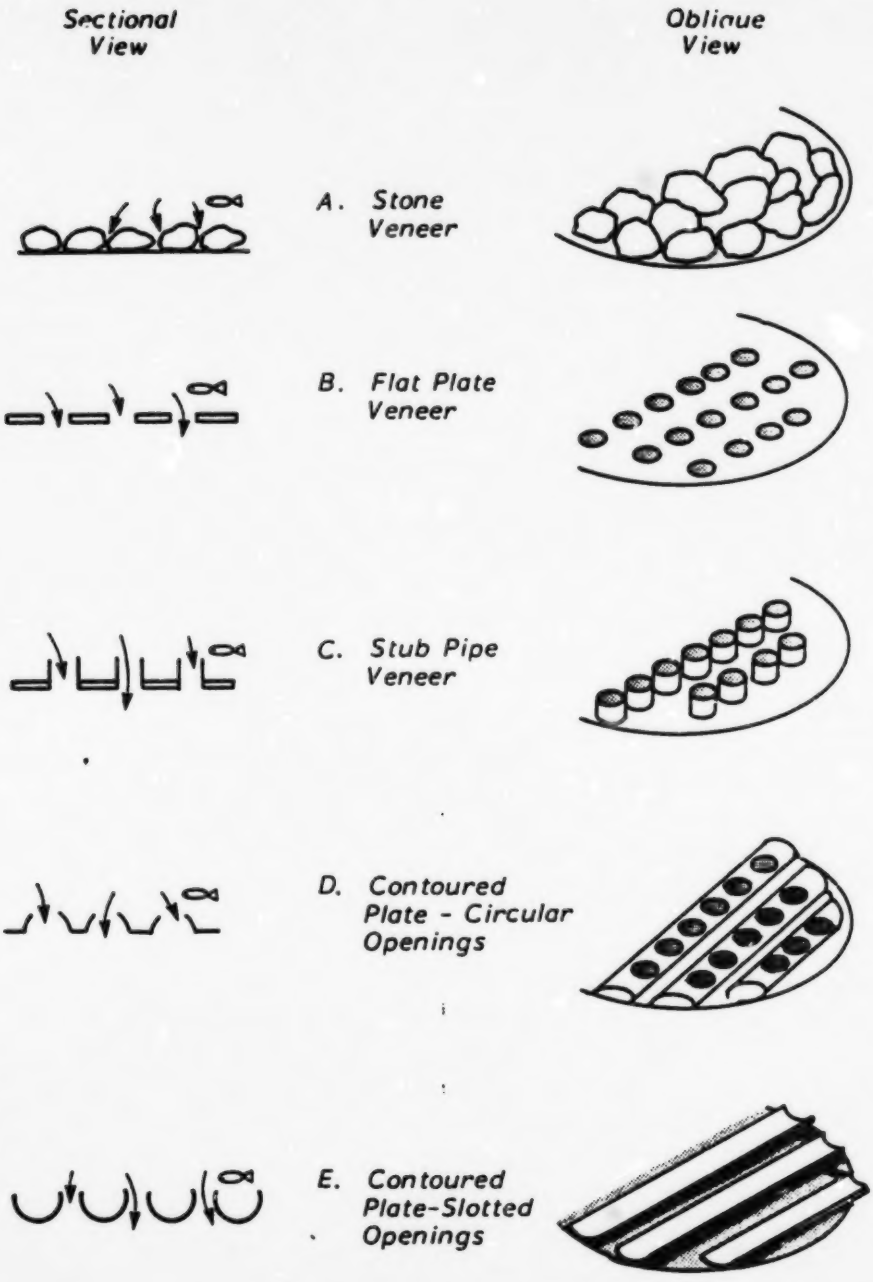



**FIGURE 2**

**POROUS INTAKE VENEERS**
**(Not Drawn to Scale)**

supported on a coarse wire mesh (Figure 2A). Vertical flows through the openings between stones were extremely variable, ranging from near zero to over 30 cm/s. While the supporting screen physically prevented test fish (10 cm to 20 cm length) from being entrained through the veneer, it was felt that impingement on the screen could occur, especially where velocities were high.

Four manufactured porous surfaces were tested, each with approximately 30% porosity. The first consisted of a 2.4 m diameter grey PVC plastic plate perforated by rows of circular holes 13 cm in diameter placed on 30 cm centres (Figure 2B). Given the size of the test fish, entrainment of fish through the veneer openings was physically possible. To prevent fish from passing through the intake pump, a coarse screen was placed over the inlet pipe, about 30 cm below the intake surface. The average flow rate through the intake openings approximated 15 cm/s but was quite variable due to local transient vortices which developed above or below the surface. The distribution of flow rates over the intake surface was also modified by the presence of cross-currents, but in general flow rates through all manufactured intake surfaces were less variable than those through the stone veneer.

The third porous surface tested was a modification of the flat plate. Short (13 cm) stub pipes were added to the surface to elevate the intake openings and create a series of "dead water" refuge areas between the intake openings (Figure 2C).

The fourth porous intake type was constructed from half-sections of 20 cm diameter PVC pipe. Rows of 13 cm diameter openings were cut into the top of the pipe sections to provide approximately 30% porosity. Flat PVC strips joining the pipe sections resulted in trough-like refuge areas between the rows of intake openings (Figure 2D).

The fifth intake type was also constructed of 20 cm diameter PVC pipe, but the sections were mounted with the concave surface facing upwards. Spaces between the pipe sections provided continuous slot openings (approximately 12 cm wide) running completely across the intake surface (Figure 2E).

## 2.3 Experimental Fish

Four species of Great Lakes fish were tested to provide representatives of both pelagic and benthic types. All were wild fish. Smelt and alewife were collected from Lake Ontario, while most of the sunfish and yellow perch were collected from the Orangeville Reservoir.

Alewife *(Alosa pseudoharengus)* and rainbow smelt *(Osmerus mordax)* were chosen as representatives of pelagic schooling species, which account for the bulk of fish impingement at most Great Lakes generating stations. Pumpkinseed sunfish *(Lepomis gibbosus)* were chosen as a representative benthic, territorial species. Some juvenile largemouth bass *(Micropterus salmoides)* were tested concurrently with the pumpkinseeds, as they were identical in size and behaved similarly. Yellow perch *(Perca flavescens)* provided a species whose behavior was assumed to be intermediate between the benthic and pelagic species. While it was initially planned to use fish ranging from 5 cm to 15 cm in length, small fish could not be clearly observed with television monitoring equipment. Hence, the mean length of test fish was about 15 cm (10 cm to 20 cm range).

## 2.4 Test Procedure

Fifty fish were used in each test. Fish used in a given replicate were introduced to the test tank and left without currents for a least one day prior to testing. They were then exposed to each current condition (intake only, intake plus minimum cross-current, intake plus maximum cross-current) for about 75 min. Minimum cross-currents approximated 3 cm/s, maximum cross-currents approximated 7 cm/s. Fish response to the intake under each condition (various current regimes plus non-current control) was monitored and recorded for 1 h (beginning 15 min after conditions were established) using a low-light TV camera and video tape recorder. Three 1-h replicates were conducted for each current condition. Different groups of fish were used for each replicate.

In addition to the tests run under low-level daylight (approximately 10 lx) experiments were also run in near darkness to simulate night conditions at an operating intake. For these studies a night viewing device (image intensifier) was added between the camera lens and body. As used in these experiments, the viewing system was probably capable of observations at light levels in the $10^{-3}$ to $10^{-4}$ lx range. As light levels were well below the measurement capabilities of any light meters available in the laboratory, the estimated light level is based on the manufacturer's (Javelin) specifications. While the "dark" experiments were not conducted in complete darkness, light levels were extremely low and the very slow movement rates exhibited by fish suggest that results are representative of night conditions (or at least, very dim twilight). For the purposes of this report, these conditions will be referred to as "twilight" rather than darkness.

The TV viewing system was mounted directly above the intake at a height (approximately 4 m) which allowed the entire intake surface and a small portion of the surrounding gravel to be

observed. However, fish were not easily visible against the gravel bottom, and could only be readily discerned when crossing the intake surface. Video tapes were monitored and each fish passing over the intake veneer was recorded. Detailed data were recorded for at least 25 single fish encounters and 5 group encounters (more than one fish) during each hour (assuming that sufficient encounters occurred during the test). Results recorded included elapsed time for the enounter, the direction of entry and exit, a record of stops or substantial turns made by the fish, and any obvious movements made to avoid intake entrainment. In alewife, perch and pumpkinseed tests with manufactured intakes surfaces, observations were expanded to include a track diagram of each fish crossing the intake surface. This procedure was begun following completion of the stone veneer tests. Hence, comparable data were not obtained for smelt, which were tested only with the stone surface.

As flow patterns through the stone veneer appear very dependent upon the placement and shape of individual stones, it was felt desirable to complete tests with all species on this surface before proceeding with the other intake surfaces. This procedure eliminated variations which would occur if the veneer were removed and reconstructed for tests with each species. As smelt were available for only a brief period in the spring of 1981, it was not possible to test smelt response to the manufactured intake surfaces. Following the stone veneer tests, alewife were tested with the four manufactured surfaces over the late summer - early fall period. Yellow perch tests were completed by late December 1981, and the pumpkinseed tests were complete by March 1982. In order that the test facility could be modified to increase the intake size and pumping capacity for subsequent studies (Ontario Hydro Research Division Report 83-351-K) the test program for pumpkinseed sunfish was curtailed. Twilight tests of pumpkinseed with the flat plate, contoured circular port and the contoured slot-port intake surfaces were eliminated from the test program.

## 3.0 RESULTS

### 3.1 Capture of Fish by Test Intakes

At the beginning of this experiment, it was assumed that a substantial portion of experimental fish would be captured by the various intake configurations tested. A total of 422 1-h tests (225 daylight, 197 twilight) was run. With 50 fish used per test, this amounts to 21 100 fish being available for capture. Only 13 fish were actually caught by the test intakes. Six captures occurred in daylight and seven occurred in twilight. All but two of these captures occurred when the intake surface was removed, leaving an open 30 cm diameter pipe at the bottom of the concrete intake basin ("no cap" condition). Thus, the

capture data cannot be used to compare the relative merits of the five intake surfaces (stone plus four manufactured surfaces) tested in this study. In addition to the capture data, ancillary data were also collected on the activity levels (number of encounters) with each intake and the behavior of fish encountering each intake (track diagrams, duration of encounters). These results will be considered to determine whether differences in fish response to the various intake surfaces can be discerned.

## 3.2 Activity Levels of Test Fish

Total numbers of encounters and captures in daylight and twilight tests are listed in Appendix 1. Substantial variations in the level of activity were apparent among the various intake surfaces tested, the species and light level used, and the current conditions of a given test. A large difference in activity level was noted for daylight and twilight tests. Over all species, the encounter level in twilight tests was approximately 12% of that observed in daylight tests. The greatest decline in activity was apparent for yellow perch, as twilight encounters were only 7% of the values obtained in daylight. Activity of alewife declined least in twilight (18% of daylight level) while twilight activity of both smelt and pumpkinseed sunfish approximated 10% of their respective daylight values.

Activity levels (total encounters) for each species and intake type in daylight tests are shown in Figure 3A. Alewife, smelt and pumpkinseeds were very active in tests of the stone veneer surface, as total encounter levels ranged from 1500 to 900 encounters (12 1-h tests were run with each species). Perch activity (260 encounters) was much lower. Smelt were tested only with the stone veneer. Alewife activity was much lower in tests of the four manufactured intake surfaces, ranging from 125 to 275 encounters for each series (of 12 tests). However, alewife activity was substantially higher (>500 encounters) in the "no cap" test series, ie, when the intake surface was removed. Yellow perch activity varied considerably. Activity levels with two of the manufactured intake surfaces (stub pipe and slotted surface) were quite low (approximately 100 encounters/test series) and were very low (50 encounters) in the "no cap" tests. However, the contoured surface with circular openings yielded quite high perch encounter levels (450 fish) and the flat plate surface tests resulted in over 1100 yellow perch encounters. Pumpkinseed activity was highest with the stone veneer (915 encounters), followed by the stub pipe surface (375 encounters), the contoured surface with circular ports (225 encounters) and the flat plate surface (170 encounters). The contoured slot-port surface and the open "no cap" control intake appeared to be actively avoided by the pumpkinseeds, as very few encounters were observed.

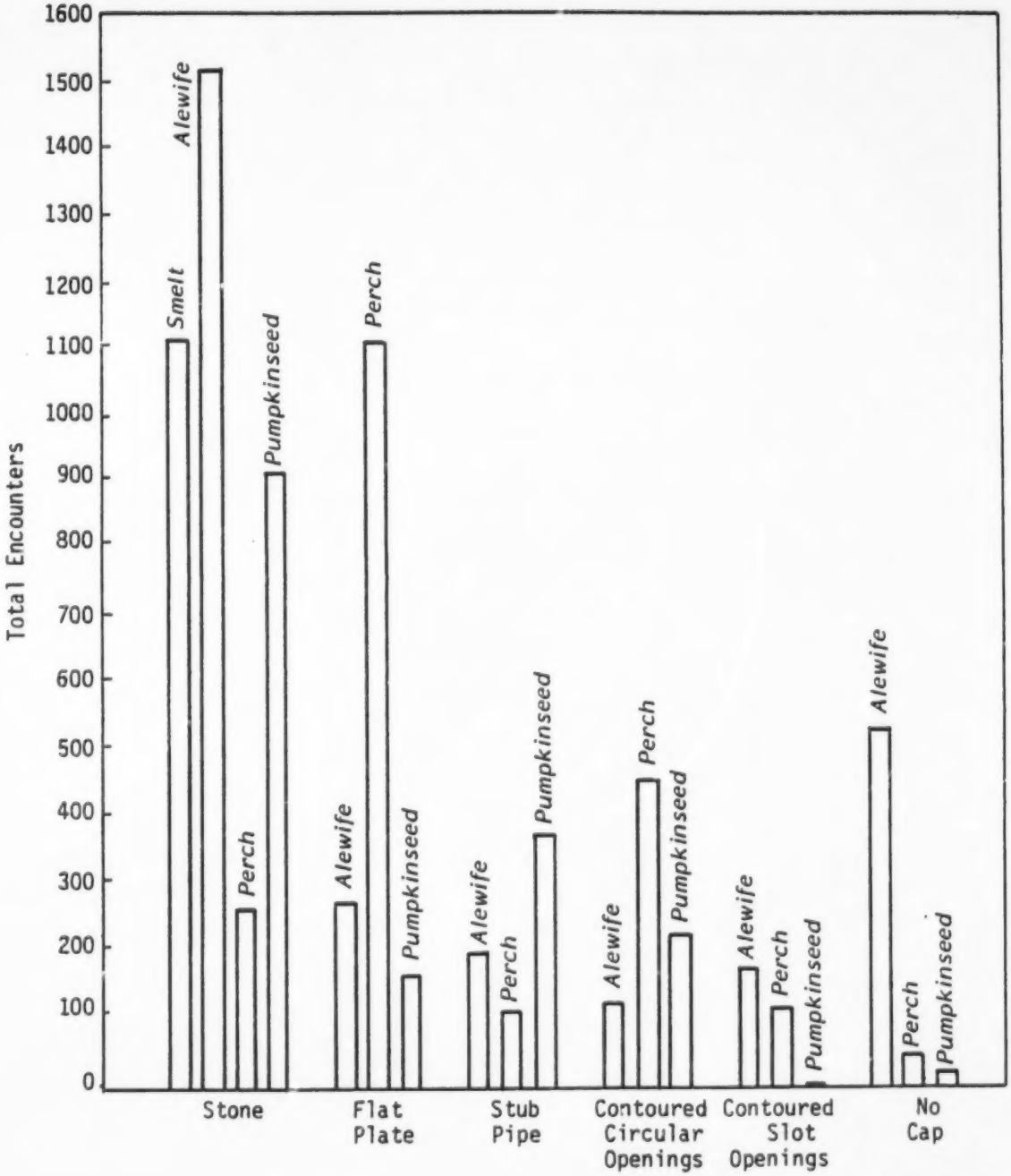



FIGURE 3A

ACTIVITY LEVELS IN DAYLIGHT TESTS
(ALL CURRENTS COMBINED)

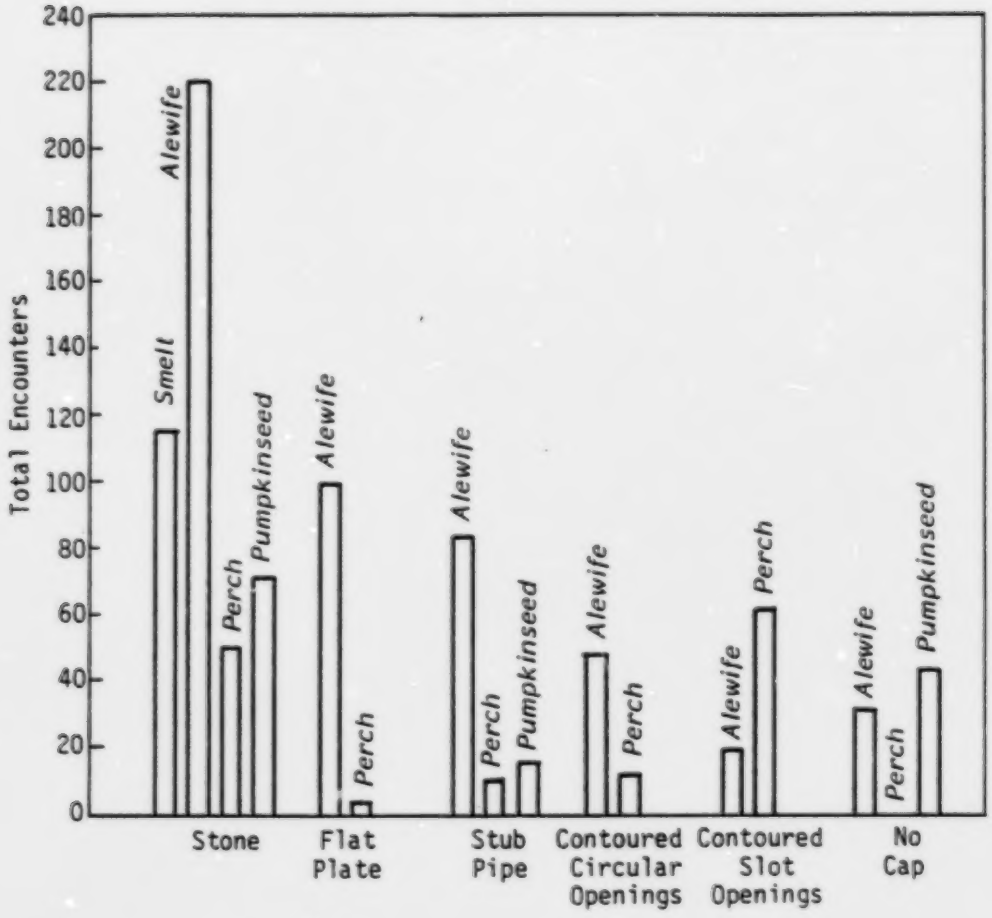



FIGURE 3B

ACTIVITY LEVELS IN TWILIGHT TESTS
(ALL CURRENTS COMBINED)

While total activity levels were reduced by approximately 90% in twilight, the proportional activity levels of the four fish species were similar to daylight results in the stone veneer tests, that is, alewife and smelt were most active, followed by pumpkinseeds, then perch (Figure 3B). Alewife activity was substantially lower in the flat plate and stub pipe intake tests. Lowest alewife activity levels were obtained in tests with the other two manufactured surfaces and the open pipe ("no cap") intake. Perch activity was moderate (50 to 60 encounters) with the stone and slotted port intakes, but extremely low with all other intake types (0 to 12 encounters). Twilight pumpkinseed tests were not conducted with the flat plate, contoured circular port and contoured slot port intakes. Encounters were very low (18) with the stub pipe intake, but moderate (42) with the open "no cap" intake. This latter test series was the only case where twilight encounter levels exceeded those observed in daylight.

In general, the encounter results suggest that the highest activity levels were observed with the stone veneer although perch results were rather variable. Tests with the four manufactured surfaces generally resulted in lower activity levels (relative to the stone tests) but there was no clear pattern of attraction to or avoidance of any particular surface. Perch appeared to avoid the open pipe "no cap" intake (which created a moderate vortex), but results for alewife and pumpkinseed were not consistent. Activity levels declined sharply between daylight and twilight tests, with yellow perch showing the greatest decline (93%) and alewife showing the least (82%).

The effects of test tank current conditions (both intake and simulated lake cross-currents) on encounter frequency are next considered (Figure 4). In order to make results comparable with the various intake surfaces, values for each current condition are expressed as a percentage of the total encounters (for a particular species) observed for each intake type. Only daylight tests are examined in detail (Figure 4) as encounter numbers in twilight tests were generally too low to allow a detailed analysis for each intake type. As four current conditions were used in the daylight tests, one would expect approximately 25% of the encounters to occur under each current condition (if results were entirely random). For smelt and alewife in the stone veneer tests (Figure 4A), this appears to be the case under no-current control conditions. However, when the intake was operating (without cross-currents) encounter frequencies increased (smelt = 72%, alewife = 46%). The addition of cross-currents reduced encounter frequency to levels which were somewhat below the no-current control values. In control (still water) tests with the stone veneer (Figure 4A)

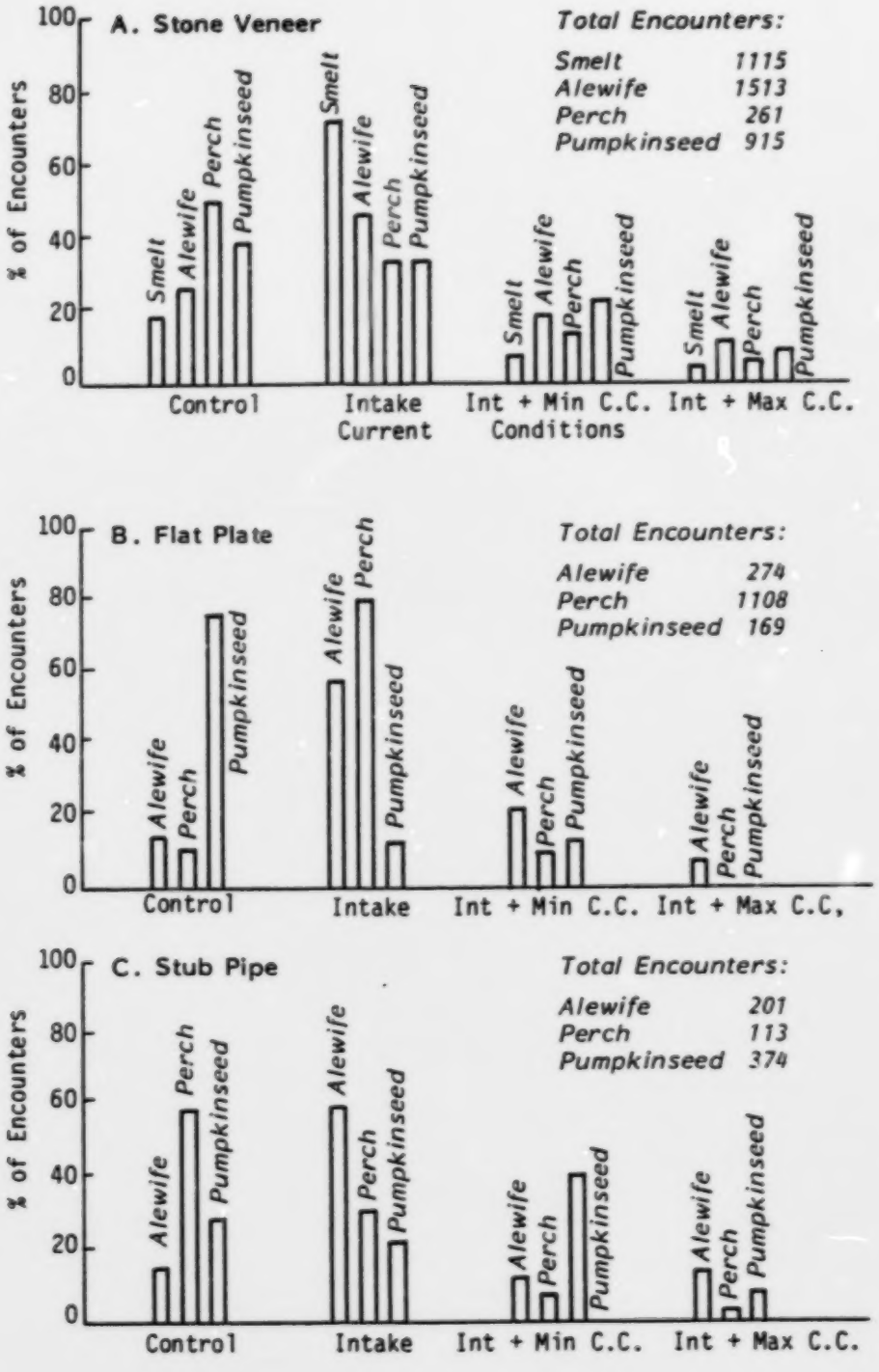



FIGURE 4

RELATIVE ENCOUNTER FREQUENCY
IN VARIOUS INTAKE CURRENTS

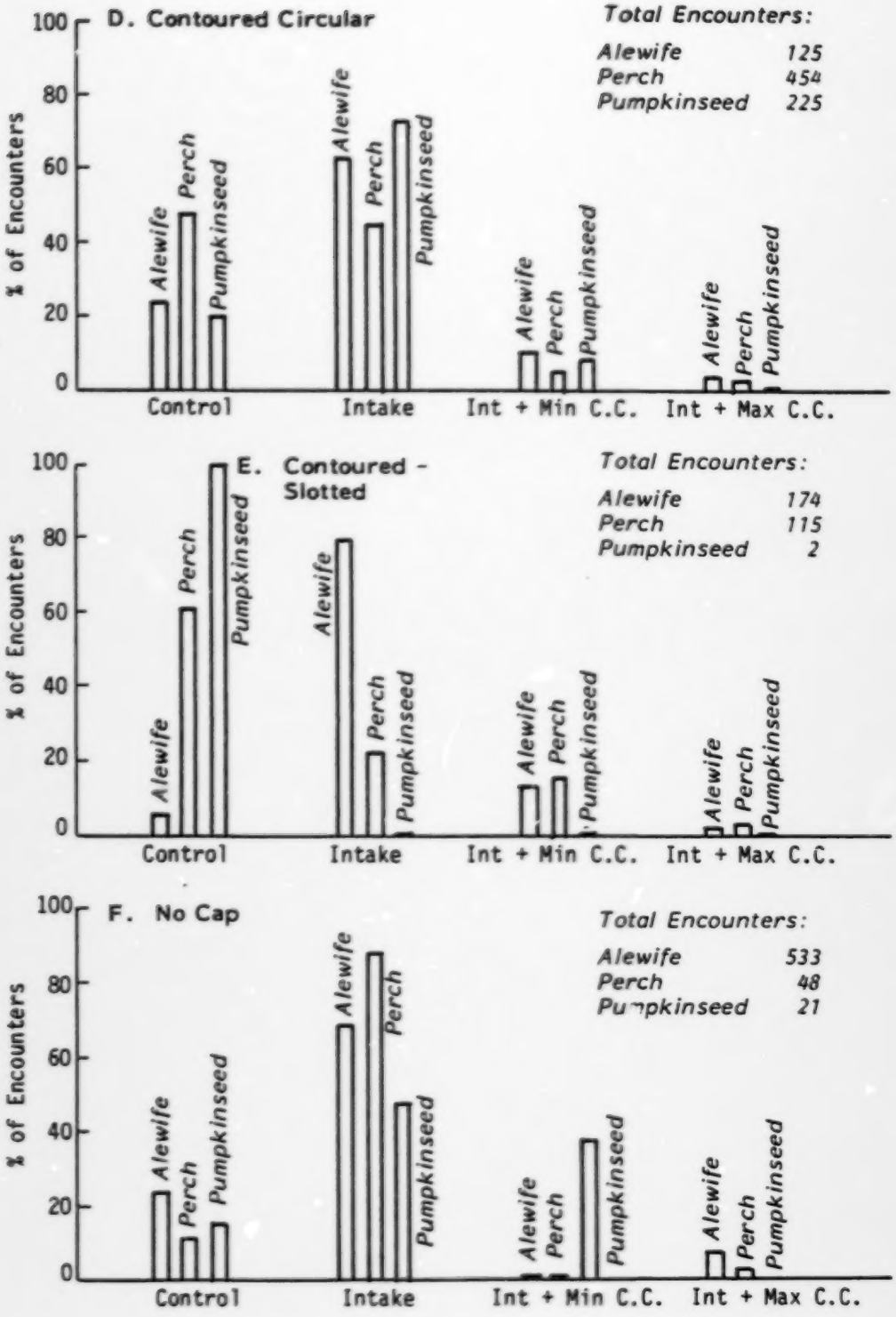



FIGURE 4 CONTINUED

RELATIVE ENCOUNTER FREQUENCY IN VARIOUS INTAKE CURRENTS

both perch and pumpkinseeds showed high encounter frequencies (38% to 50%). Encounter frequencies declined slightly in the presence of intake currents. The addition of cross-currents reduced encounter frequency of these benthic species to levels comparable to those observed for the pelagic species.

Results for the flat plate intake (Figure 4B) differ somewhat from the stone veneer data. Alewife encounters were again highest under "intake only" conditions and the pumpkinseed encounter frequency was highest under control conditions. However, the perch data were similar to the alewife data, yielding a very high encounter percentage (80%) under "intake only" conditions.

Results for the stub pipe intake surface (Figure 4C) are quite similar to those obtained from the stone surface, although encounter frequency increased for pumpkinseeds in the "intake + minimum cross-current" tests.

Alewife and perch results for the contoured surface with circular ports (Figure 4D) were also similar to encounter data for these species in stone veneer tests. With this surface, pumpkinseed encounter data were quite similar to alewife results.

In tests with the contoured slot-port intake (Figure 4E) low encounter frequency (6% of encounters) was observed for alewife under control conditions. Perch results were similar to those with the stone intake, with highest encounter frequency under static conditions and a progressive decline as current velocities in the test tank increased. Only two pumpkinseed encounters were observed, both under static (control) conditions.

In tests of the open intake pipe ("no cap"), alewife encounter frequency (Figure 4F) was similar to results with the stone veneer, although strong avoidance was apparent in the presence of cross-currents. Perch and pumpkinseed did not display the slight attraction to the static intake typical of other intake surfaces. Most encounters for these two species occurred under "intake only" conditions.

Encounter frequency in twilight tests was too low for detailed examination of each species' response to individual intakes under varying current conditions. In Figure 5, relative encounter frequency (all intakes combined) is compared for each species and current condition in daylight and twilight. Alewife show the most consistent results, as daylight and twilight results are almost identical. Smelt twilight encounters were higher (relative to daylight results) in control tests and lower in "intake only" tests. Pumpkinseed and perch twilight encounter frequencies were generally comparable to their

respective daylight values. It should be noted that percentages in Figure 5 are relative to the appropriate daylight and twilight encounter totals. Total twilight encounters of perch, pumpkinseed, smelt and alewife amounted to 6.6%, 10.1%, 10.3% and 17.8% of their respective daylight values.

The encounter data suggest that in still water the pelagic species (alewife, smelt) did not strongly prefer or avoid the intakes, as approximately 20% of all encounters were observed under control conditions. In contrast, the benthic species (perch, pumpkinseed) appeared to be slightly attracted to the test intakes, as approximately 30% to 35% of their encounters occurred under control conditions. When intake currents were established, there was a net displacement of water towards the centre of the test tank. Thus, any fish not continuously making directed movements (swimming against this current) would be carried over the intake surface. The high encounter frequency of the pelagic species under "intake only" conditions suggests that these fish did not strongly avoid the intake surfaces until they were carried directly over the surface by the intake current. Perch results under "intake only" conditions were generally similar to those of the pelagic species (Figure 5) although their response appeared to vary for different intakes (Figure 4). Pumpkinseeds had the lowest relative encounter frequency of the four test species for "intake only" tests, suggesting that this species attempted to avoid entrainment in intake currents to a greater degree than other test species. The addition of cross-currents substantiallly reduced encounter frequency for all intakes and all species. This was most evident at the highest cross-current level. These results could be interpreted as an avoidance of the intake area, or alternatively, a preference for other areas of the test tank. Visual observations suggested that during cross-current tests, fish tended to remain in an area north of the intake. As the cross-current flow was discharged from the south wall of the test tank, this area "downstream" of the intake was a relatively quiescent zone which fish appeared to prefer.

### 3.3 Fish Behavior Over Intake Surfaces

Videotape records were used to construct detailed track diagrams for tests of alewife, perch and pumpkinseeds with the four manufactured test surfaces and the open port ("no cap") control. Data were recorded on the general pathway across (or around) the intake surface and the time duration of each encounter. As these observations were begun after completion of the stone veneer tests, comparative data for the stone veneer were not collected.

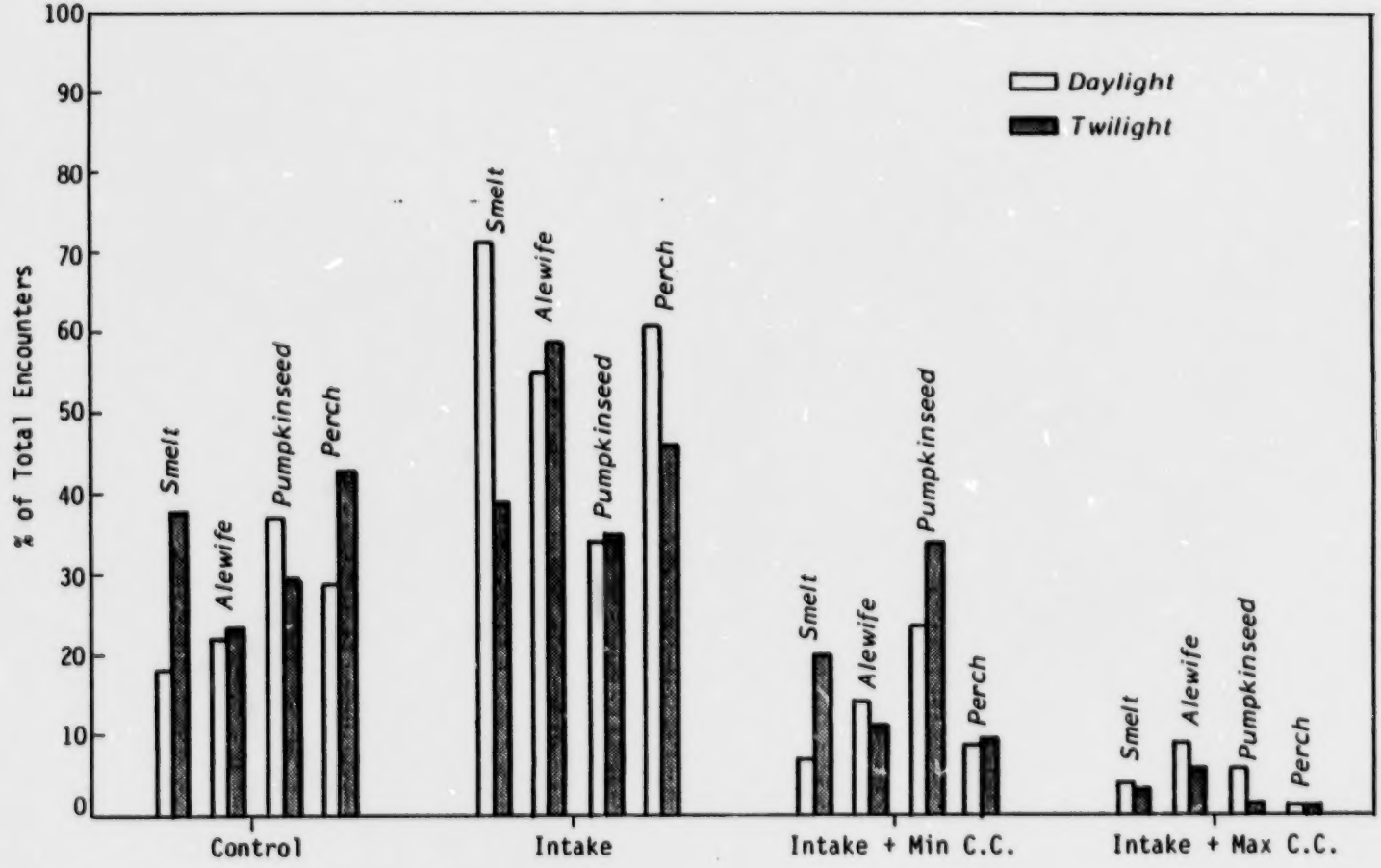



FIGURE 5

RELATIVE ENCOUNTER FREQUENCY IN VARIOUS CURRENTS
(DAYLIGHT AND TWILIGHT TESTS)

### 3.3.1 Encounter Pathways

The encounters observed were grouped into those where fish actually crossed the intake surface (the porous area containing intake ports) and those which came within the TV camera field of view (approximately 0.5 m on each side of the porous area) but did not actually cross the porous intake surfaces. For the "no cap" intake, the floor of the intake basin (approximately 0.3 m in from the lip of the basin) was assumed to represent the outer margin of this intake. Results are listed in Appendix 2.

As the number of encounters was quite limited for tests involving cross-currents, results have been combined for all tests in which an intake current was present. These have been compared with static water controls in Figure 6. Only results of daylight tests are shown, as twilight encounter frequency was very low and poor videotape quality occasionally prevented track diagrams from being constructed. Throughout the study, fine sediments which leached from the gravel in the tank bottom increased turbidity in the test tank. Repeated flushing of the tank corrected this problem only temporarily. The effects of turbidity were most acute in the twilight tests, as even moderate turbidity levels made fish extremely difficult to see on the videotape records in dim light.

Alewife in daylight tests showed moderate avoidance of the stub pipe intake (Figure 6A). Sixty per cent of the alewife encountering this intake in static water (control) crossed the surface, while 50% of the alewife encountering the operating intake crossed the surface. Of yellow perch encounters, 47% crossed the surface under control conditions and 51% crossed the operating intake.

In contrast, pumpkinseeds appeared to actively avoid crossing the stub pipe intake, with only 14% of control encounters crossing and 21% of encounters crossing when the intake was operating.

Alewife and perch encountering the flat plate intake (Figure 6B) showed very little avoidance. Approximately 80% of alewife and perch (both control and intake tests) encountering the flat plate passed over the intake surface. Pumpkinseeds showed strong avoidance of the flat plate (only 30% of control and intake encounters crossed the surface) although their avoidance was less marked than with the stub pipe intake.

Perch showed moderate avoidance of the contoured circular port intake (Figure 6C), as from 36% to 40% of the perch encountering this intake crossed the surface. Avoidance by alewife (60% to 66% crossing) and pumpkinseed (38% to 61% crossing) was only moderate.

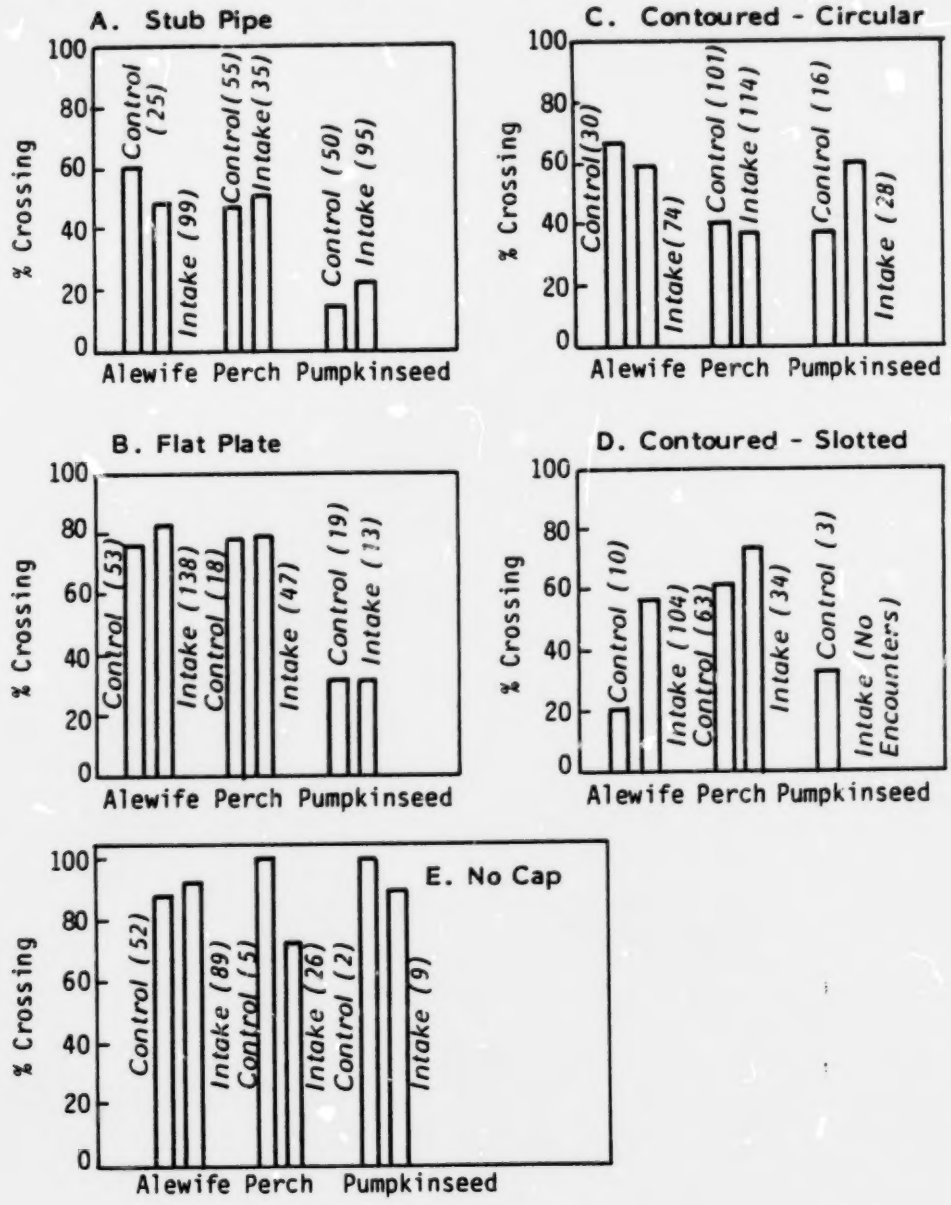



FIGURE 6

ENCOUNTER PATHWAYS - PERCENTAGE OF FISH CROSSING INTAKE SURFACES (SAMPLE SIZES IN BRACKETS)

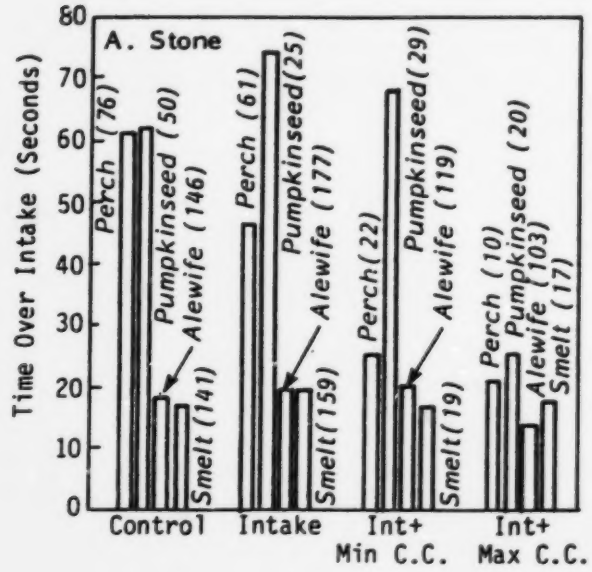
Results with the contoured slot-port intake surface (Figure 6D) were rather varied. Only 20% of alewife control encounters crossed this surface, but it should be noted that the sample size (10 encounters) was quite small. When the intake was operating, 57% of alewife encounters resulted in crossing. Perch avoidance was generally poor, with 62% of control encounters crossing and 74% of encounters crossing the operating intake. Pumpkinseed encounter levels were very low (only three fish) with this intake.

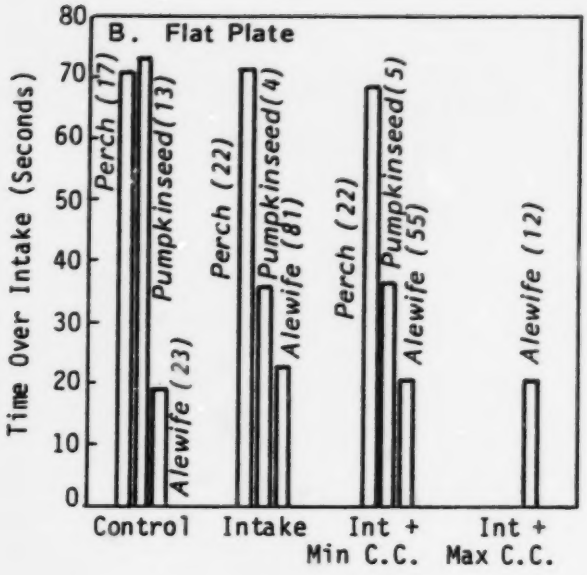
Comparison of the "no cap" open intake (Figure 6E) with the preceding results clearly demonstrates that some degree of avoidance was obtained with all surfaces, as the highest percentage crossing values for all species were obtained with this open intake. However, it should be noted that under "intake operating" conditions, perch crossings with the flat plate and slot-port intakes were comparable to those of the "no cap" intake. Also, alewife crossings of the flat plate intake (control and operating) were only slightly lower than the "no cap" results.

In general, the data in Figure 6 suggest that the stub pipe intake produced the strongest avoidance response (assessed by the proportion of fish not crossing the intake) especially for pumpkinseed sunfish. The circular port and slot port surfaces produced reasonably good avoidance (low percentage crossing) for perch and alewife respectively, but results were not consistent for all species. Poorest avoidance response was observed for the open pipe "no cap" intake, followed by the flat plate intake. Presumably, these intakes provided weaker visual cues than the other intake types. Hence fish were not stimulated to take avoidance action (skirting around the intake) until they were actually carried over the intake surface. These results suggest that an intake with some surface contour might reduce the likelihood of fish capture by providing a strong visual cue to fish encountering the intake. However, it should be remembered that in the present studies, none of the test intakes caught significant numbers of fish.

### 3.3.2 Encounter Duration

Data on the elapsed time of individual encounters is considered next. Results are listed in Appendix 3. As twilight encounter numbers were low and fish were often difficult to track on the twilight tapes, only the daylight results will be considered in detail. In tests of the stone veneer (Figure 7A) average encounter times of the pelagic species (alewife, smelt) were consistently short (14 to 20 s) over all current conditions. In contrast, mean encounter times of the benthic species (perch, pumpkinseeds) were considerably longer (over 60 s) during



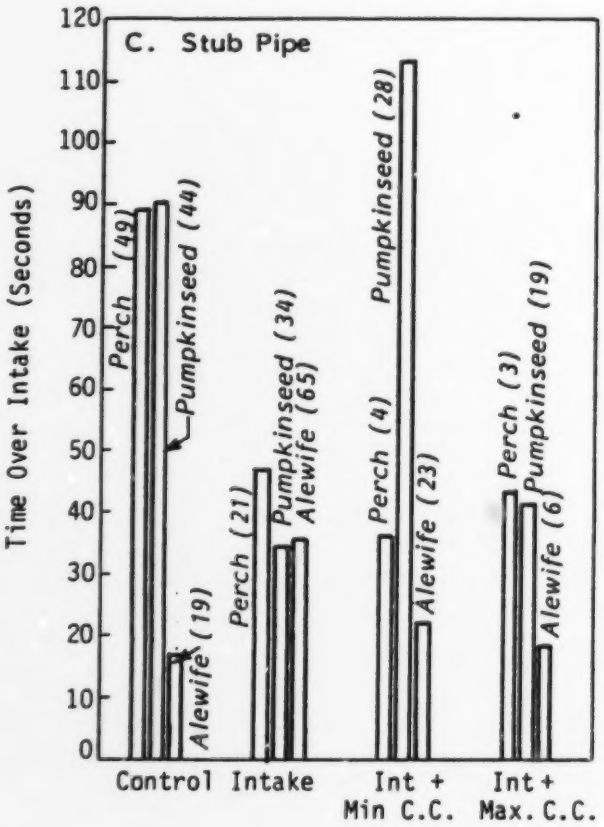




FIGURE 7

ENCOUNTER DURATIONS WITH VARIOUS INTAKES AND CURRENT CONDITIONS (SAMPLE SIZES IN BRACKETS)

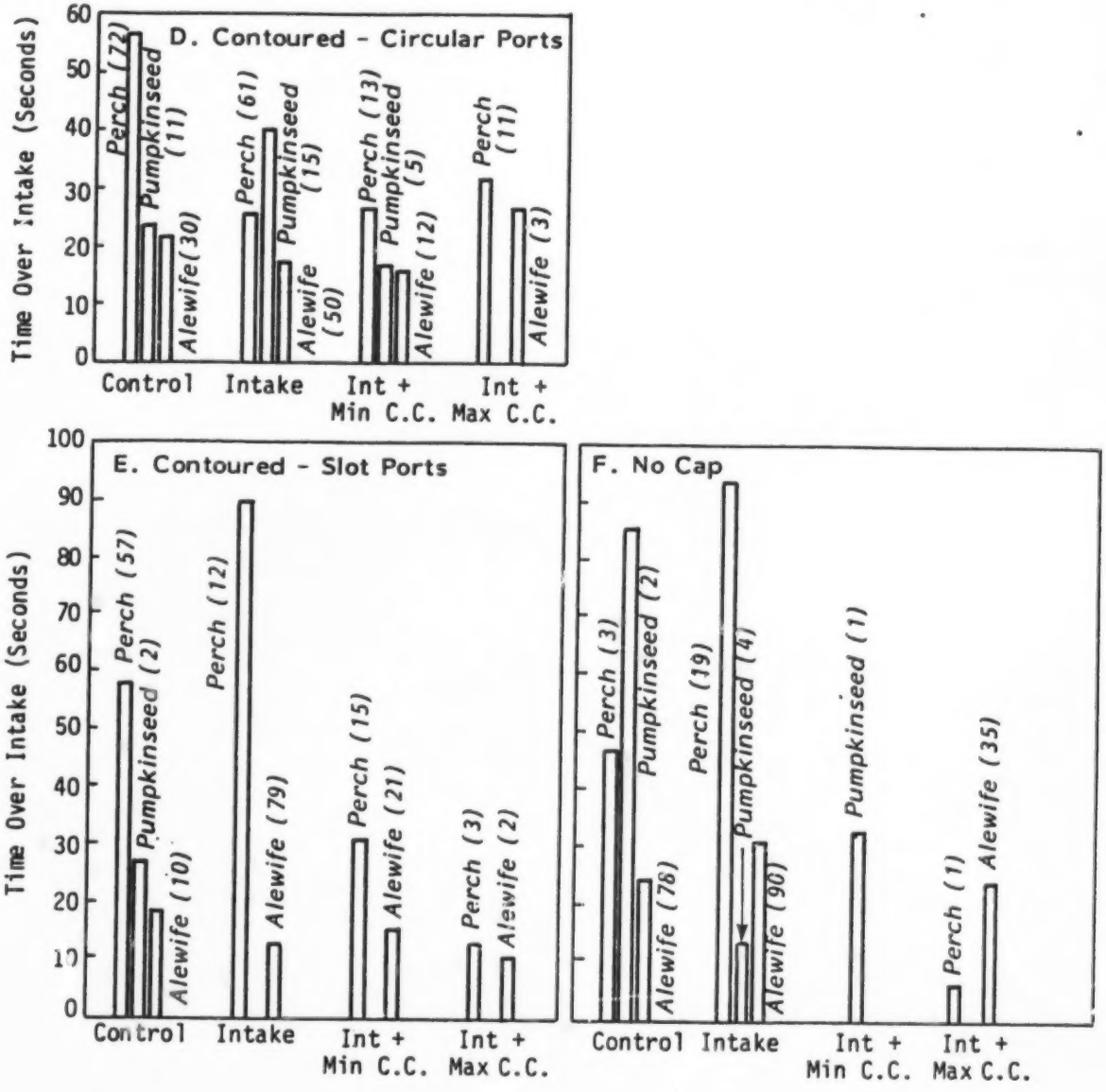



FIGURE 7 CONTINUED

ENCOUNTER DURATIONS WITH VARIOUS INTAKES AND CURRENT CONDITIONS (SAMPLE SIZES IN BRACKETS)

still-water control conditions. Variability of encounter times was also very large. While some perch and pumpkinseeds quickly passed over or around the stone veneer (as with the smelt and alewife) a substantial number of the benthic fish remained motionless over the surface for extended periods or slowly explored the stone surface. When intake currents were added, mean encounter times of perch declined slightly, but those of pumpkinseed did not. With the addition of the low velocity cross-current, perch encounter times approximated those of the pelagic species, while pumpkinseed encounter times remained high (near 70 s). The addition of a strong cross-current to the intake flow reduced both perch and pumpkinseed encounter times to the 20 to 25 s range, only slightly higher than values observed for the pelagic species.

Alewife encounter times for the flat plate intake (Figure 7B) were very comparable to those observed for the stone surface, as encounters averaged about 20 s and did not change substantially under different current conditions. Perch and pumpkinseed encounters were in excess of 70 s in static conditions. With the addition of the intake and low velocity cross-currents, pumpkinseed encounter durations declined to about 35 s but perch encounter times remained near 70 s. There were no encounters for these species under conditions of maximum cross-current.

Alewife results for the stub pipe intake (Figure 7C) differed from other surfaces, as the mean encounter time under "intake only" conditions was increased to about 35 s. Those fish which crossed the surface often changed direction and swam along the channels between the intake pipes. In still water (control), perch and pumpkinseeds oriented strongly to the stub pipes, resulting in mean encounter times near 90 s. Encounter times of these species declined to less than half this value with the addition of intake and cross-currents. However, in one case (intake + minimum cross-current) pumpkinseed encounter times were very long (>110 s). Under this condition, an eddy appeared to form at the downstream edge of the intake cap. Some pumpkinseeds moved into this eddy and remained for substantial periods (several minutes). Similar behavior was also noted under this current condition in twilight tests, resulting in a mean pumpkinseed encounter time of 98 s.

Alewife encounter times for the contoured intake with circular ports were comparable to those observed for the other intake surfaces. Perch encounter times were near 60 s in static water and declined to the 20 to 30 s range with the addition of intake and cross-currents. Pumpkinseed encounter times were generally short with this intake surface, and the number of encounters was low.

Alewife encounter times with the contoured slot-port intake (Figure 7E) were slightly lower (11 to 19 s) than with the other surfaces tested. The mean perch encounter time (58 s) in static conditions was typical of other control values. Longer encounter times (90 s) were observed under "intake only" conditions, but the addition of cross-currents again sharply reduced encounter times. Only two pumpkinseed encounters occurred in tests of this intake.

In the absence of an intake cap (Figure 7F), alewife encounter times were somewhat longer (24 to 30 s) than those observed with the various intake surfaces. Perch encounter times under "intake only" conditions were also quite long (93 s). Pumpkinseed encounter numbers (7 in total) were too low for results to be considered reliable. The somewhat longer than expected encounter times of alewife and perch under "intake only" conditions is likely the result of a substantial vortex created by the intake flow. Fish entrained into this vortex required some time to orient themselves and take avoidance action.

From the data in Figure 7 it is apparent that differences in encounter times between the intakes tested are rather minor relative to the between-species differences and the effects of current conditions. Although encounter numbers were low in twilight tests, the general pattern of response was similar to that shown in daylight tests. In Figure 8, combined results for each species (day and twilight tests, all intakes) are shown. Encounter times for the pelagic species (alewife and smelt) were typically very short (17 to 22 s) and varied only slightly with current conditions. The longest encounter times of both pelagic species occurred under "intake-only" conditions; the shortest in the presence of maximum cross-currents. The encounter times of benthic species (perch, pumpkinseeds) approximated 60 s in static conditions and declined with the addition of currents (shortest under conditions of maximum cross-current). However, pumpkinseeds tested with intake and minimum cross-currents had the longest encounter times, as some fish held position in an eddy which formed under these test conditions.

## 4.0 DISCUSSION

Capture levels in the present study were insufficient to assess the relative merits of the various intake surfaces tested (only 13 fish captured) although the results do suggest that the intake surfaces were effective at reducing fish captures, as 11 of the fish captured were entrained by the "no cap" control intake. Ancilliary data on encounter numbers, encounter pathways and encounter duration were examined to determine whether test fish responded differently to the various intake surfaces tested.

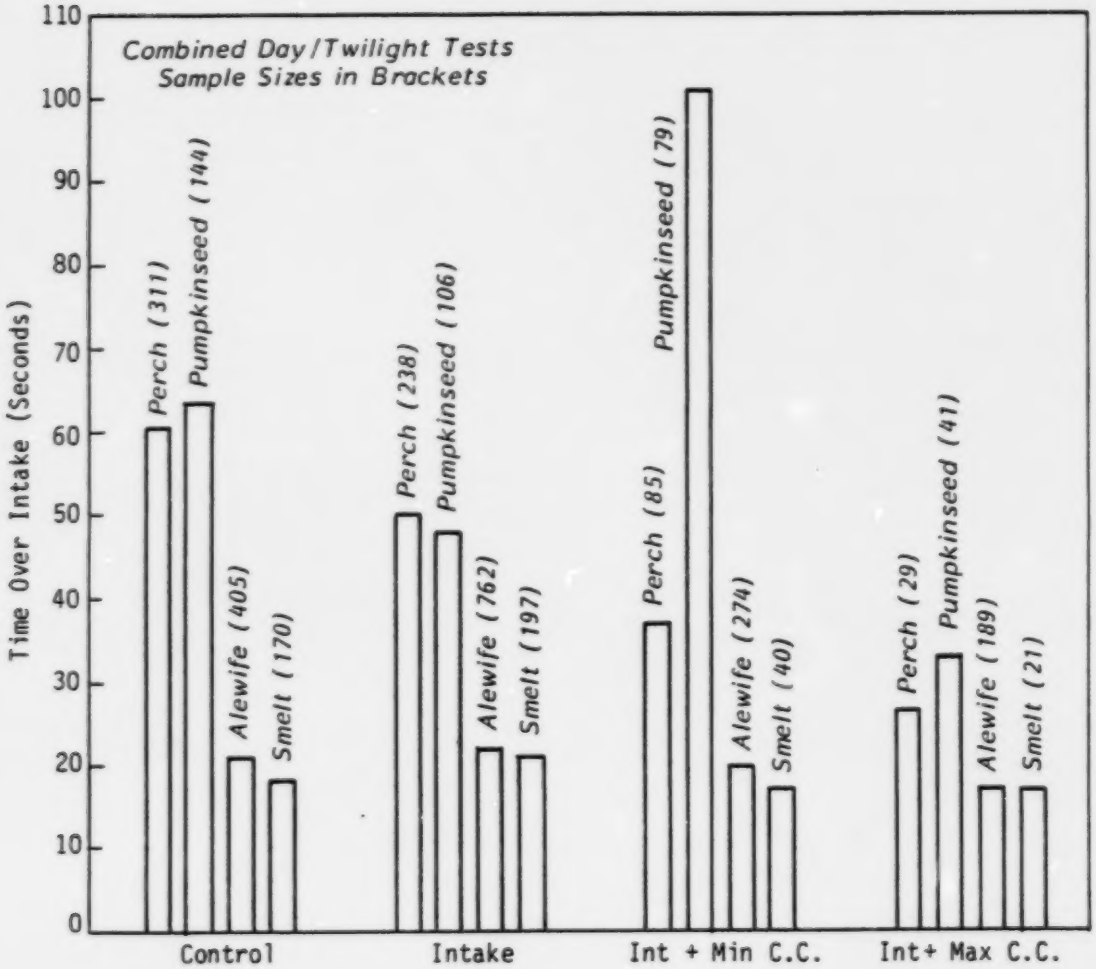



FIGURE 8

MEAN ENCOUNTER TIMES FOR EACH SPECIES
(ALL INTAKES COMBINED) IN VARIOUS CURRENTS

Data on total encounter numbers indicated that the highest encounter frequency (for all species) was observed for the stone veneer. Lower encounter frequency for the four manufactured intake surfaces suggests some degree of avoidance by test fish. This may have been due to difference in colour between the grey PVC intake surfaces and the darker surrounding gravel of the tank bottom. Comparison of present results with those obtained in subsequent studies in 1982 (Ontario Hydro Research Division Report 83-351-K) supports this contention. In the 1982 studies, the test tank and intake surfaces (flush or projecting ports) were painted a uniform light green and a larger surface (4 times the area of the 1981 intake) was used. The mean encounter rate in 1982 was 6.9 encounters/fish tested in combined daylight and twilight tests of alewife, smelt and perch. The mean value for these species during "intake only" tests during 1981 (cross-currents were not used in 1982) was 1.03 encounters/fish tested (4040 encounters for 3900 fish tested). When corrected for the difference in intake size (assuming a direct proportional relationship between intake area and encounter frequency), the 1981 value is equivalent to 4.12 encounters/fish. In comparison, the value for the stone veneer in the 1981 tests was 1.98 encounters/fish (equivalent to 7.9 encounters/fish when compared to the 1982 value). Thus, activity levels in the stone veneer tests of 1981 were comparable to the 1982 values, and the 1981 values for manufactured surfaces (which visually contrasted with the tank bottom) were considerably lower. While there is some suggestion that the intake surface structure (or lack of structure) may have influenced encounter numbers (high perch encounters with flat plate surface) results are not entirely consistent. The intake surface with contoured slot ports produced the lowest total number of encounters for alewife and pumpkinseed, and relatively low perch encounters in daylight tests. In twilight tests of this surface, alewife encounters were also very low, but perch numbers were high (pumpkinseed not tested). In general, the contoured slot-port surface appeared to have the lowest number of encounters of the surfaces tested.

Encounter numbers varied substantially in relation to illumination and test tank currents. Twilight activity levels averaged 12% of those observed in daylight, with the greatest decline being observed for yellow perch and the smallest decline for alewife. Activity levels (encounter numbers) of the pelagic species (alewife and smelt) showed no clear evidence of attraction to or avoidance of the intakes in still water (control conditions). Highest activity levels of these species were observed during "intake only" conditions as they were repeatedly carried over the surfaces by the intake currents. In the presence of cross-currents, encounters declined as the alewife and smelt avoided the intake area and took refuge in an eddy downstream of the intake surface. The benthic species appeared to

be attracted to the intake surfaces in the absence of current, as highest encounter numbers were observed under control conditions. In the presence of an intake current, perch and pumpkinseed encounters generally declined, although results were quite variable. With the addition of cross-currents, activity of these benthic species declined sharply. Like the pelagic species, they avoided the intake and sought refuge in eddies downstream of the intake surface. In the absence of an intake surface ("no cap" condition) the benthic species behaved like the alewife, that is, there was no evidence of attraction in still water and encounter frequency was highest under "intake only" current conditions.

The encounter pathway data suggests that some avoidance of all manufactured intake surfaces occurred, as percentages of encounters crossing the intake were lower than those observed in the absence of an intake cap. The stub pipe intake surface appeared to be the most effective (37.6% crossings for all species combined). The contoured circular port intake averaged 46.8% crossings, followed by the contoured slot-port intake (58.9%) and the flat plate intake (74.7%). Highest percentage crossing was observed with the open port "no cap" intake (89.1%). Thus, results suggest that those intakes which provide the strongest visual contrast to the surrounding bottom (through projecting intake ports) may reduce the likelihood of capture by inducing fish to skirt around the intake rather than pass over the porous surface.

Encounter durations of the pelagic species were typically short (approximately 20 s) and did not vary substantially under different current conditions. Encounter times of the benthic species approximated 60 s in still water (control conditions) as these fish spent considerable time holding position or slowly exploring the intake surfaces. The addition of intake currents and then cross-currents progressively decreased encounter times of the benthic species. With intake and maximum cross-currents, perch and pumpkinseed encounter times approximated those of the pelagic species.

In summary, it is evident that the ancilliary data collected in this study (encounter frequency, encounter pathways, encounter duration) do not clearly indicate which intake surfaces would be most successful in reducing capture of fish. There is a suggestion (from total encounter and encounter pathway results) that intakes with contoured surfaces (stub pipe, contoured circular or slot ports) would reduce the frequency of encounters by causing fish to divert around the porous area. Presumably, the visual cue provided by such intake surfaces is of some importance. On the basis of these results, subsequent (1982) studies utilized a larger contoured intake surface with projecting

ports and a larger intake flow. Comparison of encounter data with a flush port surface indicated greater diversion around the projecting port surface and slightly reduced capture (Ontario Hydro Research Division Report 83-351-K). However, capture differences between the two surfaces were minor and did not always consistently favour the projecting port surface.

The use of cross-currents in the present study resulted in greatly reduced encounter frequency, as test fish avoided the intakes and were attracted to eddies created downstream of the intake. In future studies of this type, the use of cross-currents does not appear warranted. Experimental systems should be designed to maximize the frequency of encounters with test intakes. The need to capture substantial numbers of test fish cannot be overemphasized. While ancilliary data on fish behavior may provide some insight into the reasons for success or failure of a given intake type, the results of the present study demonstrate that the ancilliary data alone are not sufficient to determine whether a given intake design will be acceptable. In the present case, the failure of the test system to capture fish appeared to be the result of an inadequate intake size and flow (relative to the test tank), the presence of factors which reduced the frequency of encounters (contrasting intake and bottom colour, presence of cross-currents) and the lack of tests conducted in complete darkness. In future laboratory studies of intakes or diversion barriers, every effort should be made to assure that a substantial portion of fish will be captured by the test system, allowing direct comparison of various intakes on the basis of total captures and capture/encounter data.

## 5.0 SUMMARY

1. The response of Great Lakes fish species to 2 m diameter full-scale sections of porous CCW intakes operated at full-scale velocities was determined in a large (15 m x 15 m) laboratory test tank. Tests were conducted in static water (control), with intake currents, and with two levels of cross-currents (3cm/s and 7 cm/s). Both daylight and twilight tests were run. Alewife and rainbow smelt were representative pelagic schooling species tested. Yellow perch and pumpkinseed sunfish were representative benthic species tested. Four manufactured (PVC) intake surfaces, a natural stone veneer and an open pipe (control) intake were tested under the conditions outlined above.

2. Capture data were insufficient to evaluate the relative merits of the intake surfaces tested. In 422 1-h tests (50 fish/test) only 13 fish were captured. Eleven of these fish were captured by the open pipe ("no cap") intake.

3. Ancilliary data were examined to determine whether differences in fish response to the various intake surfaces could be discerned. Total encounter results indicate the highest activity levels with the stone intake veneer. Tests with the four manufactured surfaces resulted in lower activity levels, but there was no clear pattern of attraction to or avoidance of any particular surface. Activity levels declined sharply between daylight and twilight tests, with yellow perch showing the greatest decline (93%) and alewife showing the least (82%).

4. In relation to intake currents, the pelagic species (alewife, smelt) showed little attraction to the intake in still water (control). In the presence of the intake flow, pelagic species showed high encounter rates as they were repeatedly carried over the intake surface. Benthic species (yellow perch, pumpkinseeds) appeared to be attracted to the intake surfaces in still water, but their encounter frequency declined subtantially with the addition of currents to the test tank. In the presence of both intake and maximum cross-currents, all species avoided test intakes and sought refuge in a large eddy which formed "downstream" of the intake surfaces.

5. Encounter pathway data from videotapes suggest some avoidance of all manufactured intake surfaces (compared with "no cap" control). The intakes with the most obvious surface contour appeared more effective in diverting test fish around the porous surface, but results were not consistent for all species and test conditions.

6. Encounter durations of the pelagic species were typically short (approximately 20 s) and did not vary substantially under different current conditions. Encounter times of benthic species approximated 60 s in still water but progressively decreased (to approximately 20 s) with the addition of intake and cross-currents. There were no consistent differences in encounter times for the various intake surfaces tested.

7. The ancilliary data collected in this study (encounter frequency, encounter pathways, encounter duration) did not clearly indicate which intake surfaces would be most successful in reducing fish capture. While such ancilliary data may be useful in interpreting capture results, it is emphasized that in future studies of intakes or diversion barriers, the laboratory system must be capable of capturing a substantial portion of test fish, allowing comparison of intakes on the basis of total capture or capture/encounter data. Larger intake surfaces, larger intake flows, elimination of cross-currents and visual contrast (colour) between the intake and the remainder of the tank are recommended as means to assure capture of test fish. The inclusion of tests in complete darkness is also recommended for studies of this type.

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Manager
Chemical Research Dept

Submitted:

J.S. Griffiths
Biologist
Biological Research Section

JSG:lg

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## APPENDIX 1 - A. DAYLIGHT TESTS

### TOTAL ENCOUNTERS AND CAPTURES* BY POROUS INTAKES

| Intake Type/Current | Yellow Perch | Pumpkinseed Sunfish | Alewife | Smelt |
|---|---|---|---|---|
| A. Rock | | | | |
| 1. Control | 129 | 342 | 387 | 149 |
| 2. Intake | 87 | 198 | 693 | 799 |
| 3. Int + Min CC | 33 | 201 | 267 | 75 |
| 4. Int + Max CC | 12 | 74 | 166 | 42 |
| B. Flat Plate | | | | |
| 1. Control | 113 | 128 | 37 | - |
| 2. Intake | 888 | 21 | 156 | - |
| 3. Int + Min CC | 107 | 20 | 61 | - |
| 4. Int + Max CC | 0 | 0 | 20 | - |
| C. Stub Pipe | | | | |
| 1. Control | 67 | 108 | 30 | - |
| 2. Intake | 35 | 83 | 120 | - |
| 3. Int + Min CC | 8 | 154 | 24 | - |
| 4. Int + Max CC | 3 | 29 | 27 | - |
| D. Contoured/Circular | | | | |
| 1. Control | 218 | 44 | 30 | - |
| 2. Intake | 204 | 163(1) | 78 | - |
| 3. Int + Min CC | 21 | 18 | 13 | - |
| 4. Int + Max CC | 11 | 0 | 4 | - |
| E. Contoured/Slotted | | | | |
| 1. Control | 70 | 2 | 10 | - |
| 2. Intake | 25 | 0 | 139 | - |
| 3. Int + Min CC | 17 | 0 | 23(1) | - |
| 4. Int + Max CC | 3 | 0 | 2 | - |
| F. No Cap | | | | |
| 1. Control | 5 | 3 | 129 | - |
| 2. Intake | 42 (1) | 10 | 365(2) | - |
| 3. Int + Min CC | - | 8 | 0 | - |
| 4. Int + Max CC | 1 | 0 | 39(2) | - |

* where captures occurred, numbers shown in brackets
\- indicates tests not run

## APPENDIX 1 - B. TWILIGHT TESTS

### TOTAL ENCOUNTERS AND CAPTURES* BY POROUS INTAKES

| Intake Type/Current | Yellow Perch | Pumpkinseed Sunfish | Alewife | Smelt |
|---|---|---|---|---|
| A. Rock | | | | |
| 1. Control | 25 | 29 | 35 | 43 |
| 2. Intake | 21 | 35 | 135 | 45 |
| 3. Int + Min CC | 4 | 7 | 32 | 23 |
| 4. Int + Max CC | 0 | 1 | 18 | 4 |
| B. Flat Plate | | | | |
| 1. Control | 0 | - | 42 | - |
| 2. Intake | 1 | - | 51 | - |
| 3. Int + Min CC | 3 | - | 6 | - |
| 4. Int + Max CC | 0 | - | 0 | - |
| C. Stub Pipe | | | | |
| 1. Control | 7 | 5 | 23 | - |
| 2. Intake | 4 | 8 | 51 | - |
| 3. Int + Min CC | 0 | 3 | 3 | - |
| 4. Int + Max CC | 0 | - | 6 | - |
| D. Contoured/Circular | | | | |
| 1. Control | 3 | - | 12 | - |
| 2. Intake | 8 | - | 21 | - |
| 3. Int + Min CC | 1 | - | 11 | - |
| 4. Int + Max CC | 0 | - | 4 | - |
| E. Contoured/Slotted | | | | |
| 1. Control | 25 | - | 1 | - |
| 2. Intake | 30 | - | 15 | - |
| 3. Int + Min CC | 5 | - | 3 | - |
| 4. Int + Max CC | 2 | - | 1 | - |
| F. No Cap | | | | |
| 1. Control | 0 | 5 | 3 | - |
| 2. Intake | 0 | 3 | 27 | - |
| 3. Int + Min CC | 0 | 35(7) | - | - |
| 4. Int + Max CC | 0 | 1 | 1 | - |

* where captures occurred, numbers shown in brackets
\- indicates tests not run

## APPENDIX 2 - FISH BEHAVIOR DURING ENCOUNTERS (DAYLIGHT)

| Intake Type and Current | Alewife | | Perch | | Pumpkinseed | |
|---|---|---|---|---|---|---|
| | Encounters Monitored | % Crossing Intake | Encounters Monitored | % Crossing Intake | Encounters Monitored | % Crossing Intake |
| **Flat Plate** | | | | | | |
| Control | 53 | 75.5 | 18 | 77.8 | 19 | 31.6 |
| Intake | 84 | 82.1 | 23 | 87.0 | 4 | 25.0 |
| Int + Min CC | 40 | 80.0 | 24 | 70.8 | 9 | 33.3 |
| Int + Max CC | 14 | 92.9 | 0 | - | 0 | - |
| All Intake | 138 | 82.6 | 47 | 78.7 | 13 | 30.8 |
| **Stub Pipe** | | | | | | |
| Control | 25 | 60.0 | 55 | 47.3 | 50 | 14.0 |
| Intake | 70 | 47.2 | 22 | 45.5 | 44 | 18.2 |
| Int + Min CC | 23 | 60.9 | 8 | 75.0 | 31 | 32.8 |
| Int + Max CC | 6 | 16.7 | 5 | 40.0 | 20 | 15.0 |
| All Intake | 99 | 48.5 | 35 | 51.4 | 95 | 22.1 |
| **Contoured/Circular** | | | | | | |
| Control | 30 | 66.7 | 101 | 40.6 | 16 | 37.5 |
| Intake | 58 | 62.1 | 84 | 38.1 | 21 | 66.7 |
| Int + Min CC | 12 | 50.0 | 19 | 36.8 | 7 | 42.9 |
| Int + Max CC | 4 | 50.0 | 11 | 27.3 | 0 | - |
| All Intake | 74 | 59.5 | 114 | 36.8 | 28 | 60.7 |
| **Contoured/Slotted** | | | | | | |
| Control | 10 | 20.0 | 63 | 61.9 | 3 | 33.3 |
| Intake | 81 | 56.8 | 14 | 78.6 | 0 | - |
| Int + Min CC | 21 | 52.4 | 17 | 70.6 | 0 | - |
| Int + Max CC | 2 | 100.0 | 3 | 66.7 | 0 | - |
| All Intake | 104 | 56.7 | 34 | 73.5 | 0 | - |
| **No Cap** | | | | | | |
| Control | 52 | 88.5 | 5 | 100.0 | 2 | 100.0 |
| All Intake | 89 | 93.3 | 26 | 73.1 | 9 | 88.9 |

## APPENDIX 3 - A. DAYLIGHT TESTS

### MEAN TIMES (SECONDS) SPEND ON VENEER*

| Intake Type/Current | Perch | Pumpkinseed | Alewife | Smelt |
|---|---|---|---|---|
| A. Rock | | | | |
| 1. Control | 61.2 (76) | 61.8 (50) | 18.0 (146) | 17.0 (141) |
| 2. Intake | 46.4 (61) | 74.5 (25) | 19.4 (177) | 18.8 (159) |
| 3. Int + Min CC | 25.5 (22) | 68.3 (29) | 19.9 (119) | 16.8 (19) |
| 4. Int + Max CC | 20.9 (10) | 25.5 (20) | 13.7 (103) | 17.4 (17) |
| B. Flat Plate | | | | |
| 1. Control | 70.8 (17) | 72.8 (13) | 18.9 (23) | - |
| 2. Intake | 71.5 (22) | 35.5 (4) | 23.2 (81) | - |
| 3. Int + Min CC | 68.6 (22) | 36.4 (5) | 20.7 (55) | - |
| 4. Int + Max CC | - | - | 20.0 (12) | - |
| C. Stub Pipe | | | | |
| 1. Control | 88.7 (49) | 90.4 (44) | 16.8 (19) | - |
| 2. Intake | 46.9 (21) | 34.3 (34) | 35.1 (65) | - |
| 3. Int + Min CC | 35.8 (4) | 112.9 (28) | 21.4 (23) | - |
| 4. Int + Max CC | 42.7 (3) | 40.8 (19) | 18.0 (6) | - |
| D. Contoured/Circular | | | | |
| 1. Control | 57.1 (72) | 23.6 (11) | 21.8 (30) | - |
| 2. Intake | 25.5 (61) | 40.2 (15) | 17.5 (50) | - |
| 3. Int + Min CC | 26.7 (13) | 17.0 (5) | 15.7 (12) | - |
| 4. Int + Max CC | 31.7 (11) | - | 26.7 (3) | - |
| E. Contoured/Slotted | | | | |
| 1. Control | 57.8 (57) | 26.5 (2) | 18.7 (10) | - |
| 2. Intake | 89.6 (12) | - | 12.7 (79) | - |
| 3. Int + Min CC | 31.2 (15) | - | 15.5 (21) | - |
| 4. Int + Max CC | 13.0 (3) | - | 11.0 (2) | - |
| F. No Cap | | | | |
| 1. Control | 46.7 (3) | 85.5 (2) | 24.2 (78) | - |
| 2. Intake | 92.8 (19) | 12.8 (4) | 30.5 (90) | - |
| 3. Int + Min CC | - | 33.0 (1) | - | - |
| 4. Int + Max CC | 6.0 (1) | - | 24.3 (35) | - |

* Sample sizes are shown in brackets

## APPENDIX 3 - B. TWILIGHT TESTS

### MEAN TIMES (SECONDS) SPENT ON VENEER*

| Intake Type/Current | Perch | Pumpkinseed | Alewife | Smelt |
|---|---|---|---|---|
| A. Rock | | | | |
| 1. Control | 20.2 (18) | 27.9 (15) | 30.0 (30) | 22.8 (29) |
| 2. Intake | 46.0 (17) | 30.4 (15) | 15.4 (83) | 28.8 (38) |
| 3. Int + Min CC | 7.3 (3) | 37.5 (2) | 20.3 (22) | 17.6 (21) |
| 4. Int + Max CC | - | 45.0 (1) | 18.8 (17) | 15.0 (4) |
| B. Flat Plate | | | | |
| 1. Control | - | - | 25.2 (38) | - |
| 2. Intake | 11.0 (1) | - | 32.6 (36) | - |
| 3. Int + Min CC | 11.0 (2) | - | 21.7 (6) | - |
| 4. Int + Max CC | - | - | - | - |
| C. Stub Pipe | | | | |
| 1. Control | 27.8 (6) | 46.8 (4) | 17.8 (16) | - |
| 2. Intake | 19.9 (4) | 97.5 (8) | 30.5 (44) | - |
| 3. Int + Min CC | - | 51.7 (3) | 15.5 (2) | - |
| 4. Int + Max CC | - | - | 19.2 (6) | - |
| D. Contoured/Circular | | | | |
| 1. Control | 25.0 (1) | - | 18.6 (11) | - |
| 2. Intake | 8.5 (2) | - | 14.4 (20) | - |
| 3. Int + Min CC | - | - | 23.1 (11) | - |
| 4. Int + Max CC | - | - | 11.3 (3) | - |
| E. Contoured/Slotted | | | | |
| 1. Control | 48.7 (12) | - | 20.1 (1) | - |
| 2. Intake | 31.3 (18) | - | 14.8 (12) | - |
| 3. Int + Min CC | 21.8 (4) | - | 13.0 (3) | - |
| 4. Int + Max CC | 32.0 (1) | - | 5.0 (1) | - |
| F. No Cap | | | | |
| 1. Control | - | 14.7 (3) | 8.0 (3) | - |
| 2. Intake | - | 35.0 (1) | 15.6 (25) | - |
| 3. Int + Min CC | - | 384.7 (6) | - | - |
| 4. Int + Max CC | - | 36.0 (1) | 19.0 (1) | - |

* Sample sizes are shown in brackets